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Evaluation of 20th century decadal climate variability from massive scleractinian pinnacle corals from La Parguera, Puerto Rico,northeast Caribbean Sea

Robert S. Webb[1], Amos Winter[2], Henry F. Diaz[1], Jon K. Eischeid[1]

[1]NOAA-CIRES Climate Diagnostics Center, Boulder, CO [2]Department of Marine Sciences, University of Puerto Rico, Mayaguez, PR

1. Background

The paleoclimate record provides the needed long-term perspective to improve understanding of the role of the tropical Atlantic Ocean in decadal to multidecadal climate variability. In this study we assess the use of a multicentury geochemical record of climate variability from massive scleractinian pinnacle corals near Puerto Rico in the eastern Caribbean (Figure 1) to reconstruct an extended record of upper ocean conditions in the tropical North Atlantic (Figure 2). We first use the instrumental record of multidecadal climate variability and then evaluate the fidelity of 20th century geochemical record of multidecadal climate variability preserved with the coral record.

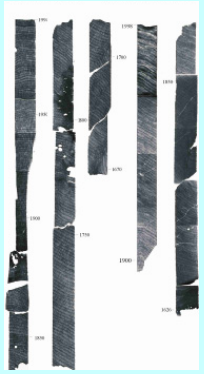

Figure 1. X-radiographs of 3mm thick slabs cut along the longitudinal axes of the *Mantastrea faveolata* coral cores from colonies adjacent to each other at 7 m water depth.

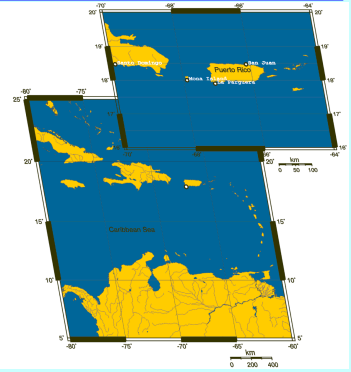

Figure 2. Caribbean and regional map showing the site locations for ca. 350 year long continuous *Mantastrea faveolata* coral records from La Parguera

2. Caribbean representation of large scale multidecadal climate variability

Analysis of a 120 year composite marine global annual temperature dataset gridded at 5°x 5° resolution indicates that the northeastern Caribbean is highly representative of the global and Atlantic Basin decadal climate variability. To focus on decadal to multidecadal variability we have filtered the global and Puerto Rico mean annual sea surface temperature time series to remove the long term 100-year trend and subdecadal variability. Analyses using spatial correlation maps comparing Global (Figure 3a) and Puerto Rico (Figure 3b) annual SST time series with data for the rest of the globe, indicate that the northeast Caribbean is well suited for investigations of the spatial and temporal patterns of decadal climate variability at tropical Atlantic to global scales. Correlations between the filtered and detrended southwest Puerto Rico SST times series with time series of global surface temperature, global SSTs, global tropical SSTs, the Atlantic Multidecadal Oscillation (AMO), and the Pacific Decadal Index (PDI *aka PDO*) for the entire 120 year and two 60 year segments of the record (1881-1940 and 1941-2000) underscore the persistence of this local region to represent larger scale climate variability for much of the last 120 years (Table 1, Figure 4)

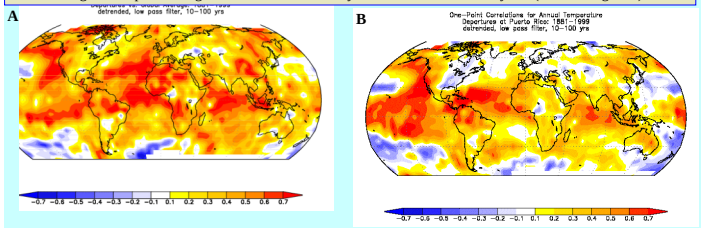

Figure 3. Global spatial correlation maps of the covariance between the times series from individual 5°x5° grid boxes and the global surface air temperature time series (A) and the grid box of southwest Puerto Rico SST time series (B)

3. Correlations of coral isotope SST & indices of multidecadal climate variability

Oxygen isotope-derived SST timeseries from already recovered coral material off the coast of Puerto Rico was also filtered to remove the long term 100-year trend and subdecadal variability prior to examining correlations with the filtered and detrended times series of SSTs southwest Puerto Rico, global surface temperature, global SSTs, global tropical SSTs, the AMO, and the PD (Figure 4). Correlation between time series were calculated for the entire 110 year and two 55 year segments of the record (1881-1935 and 1936-1990) . In contrast with the comparison of southwest Puerto Rico observation-based SST times series to a suite of regional and global time series, the correlations between the coral-derived SST time series and the suite of observation-based times series are only significant for the period 1936 to 1990 (Table 2) On their own, the results for the 1936-1990 comparisons show promise for generating multicentury reconstructions of SSTs to extend our ability to understand tropical North Atlantic multidecadal climate variability, patterns, and teleconnections into the past few centuries. Additional correlation analyses indicate that prior to 1925 the modes of variability represented in the coral oxygen-isotope record do not represent simply changes in SST. Furthermore, even for the 1936-1990 period, the coral oxygen-isotope record has higher correlations with global SSTs and global surface air temperature than the local SST record.

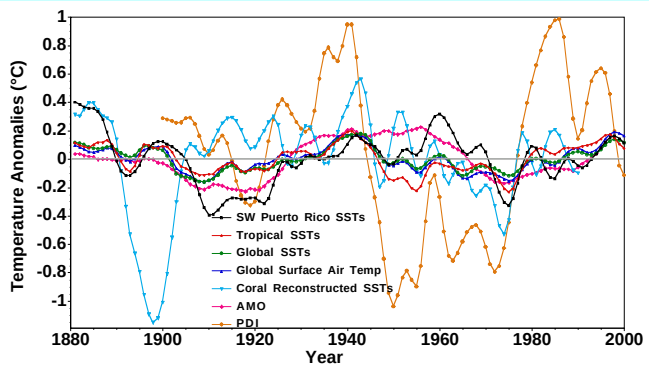

Figure 4. Graph of filtered and detrended observation-based and coral reconstructed time series evaluated in this study. The coral reconstruction suggests anomalously cold SSTs during the 1890s that are not present in any of the instrumental-based temperature time series whereas the local SSTs observations were cold in the 1910-1925 period.

Table 1. *Pearson's r* and tests for correlation significance between southwest Puerto Rico SST times series and suite of time series for two 60 year segments of the record and the entire 120 years.

1881 to 1940	r	prob	z
Tropical SSTs	0.7693	0.1039E-23	1.019
AMO	0.6419	0.2779E-14	0.7614
PDI	0.3438	0.1208E-03	0.3584
Global SSTs	0.6285	0.1534E-13	0.7389
Global Surface Air Temperature	0.6300	0.1267E-13	0.7414
1941 to 2000			
Tropical SSTs	0.7762	0.2149E-24	1.036
AMO	0.1300	0.1572E+00	0.1307
PDI	0.6894	0.3170E-17	0.8467
Global SSTs	0.5755	0.6184E-11	0.6557
Global Surface Air Temperature	0.5864	0.1971E-11	0.6721
1881 to 2000			
Tropical SSTs	0.7278	0.4659E-20	0.9241
AMO	0.4024	0.5212E-05	0.4265
PDI	0.4716	0.5414E-07	0.5121
Global SSTs	0.6047	0.2611E-12	0.7004
Global Surface Air Temperature	0.5918	0.1098E-11	0.6804

Table 2. *Pearson's r* and significance between coral Oxygen isotope-derived SST time series and a suite of time series for two 55-year segments of the record and 110 years.

1881 to 1935	r	prob	z
SSTs SW of Puerto Rico	-0.2110	0.0206	-0.2142
Tropical SSTs	-0.1818	0.0469	-0.1838
AMO	-0.1681	0.0664	-0.1697
PDI	-0.0330	0.7203	-0.0330
Global SSTs	-0.2514	0.0056	-0.2569
Global Surface Air Temperature	-0.2512	0.0056	-0.2567
1936 to 1990			
SSTs SW of Puerto Rico	0.5183	0.1330E-08	0.5741
Tropical SSTs	0.5512	0.6867E-10	0.6201
AMO	0.5317	0.4122E-09	0.5926
PDI	0.4538	0.1940E-06	0.4894
Global SSTs	0.7059	0.2199E-18	0.8789
Global Surface Air Temperature	0.6834	0.8026E-17	0.8354
1881 to 1990			
SSTs SW of Puerto Rico	0.0049	0.9575	0.0049
Tropical SSTs	0.1216	0.1859	0.1222
AMO	0.1317	0.1517	0.1324
PDI	0.1819	0.0467	0.1839
Global SSTs	0.0950	0.3016	0.0953
Global Surface Air Temperature	0.1276	0.1647	0.1283

4. Multidecadal climate variability in the coral $\delta^{18}O$ record

Previous work by Winter (*pers. comm.*) evaluating high resolution climate and isotope data for the 5 year period (1984-1989) suggested the influence of precipitation was on the order of 36 percent of the measured variance in coral $\delta^{18}O$. Given these results and the fact that the coral oxygen-isotope record was better correlated with both global SSTs and global surface air temperature than the local SSTs, the impact of precipitation variability on the coral record is evaluated for the 1936 to 1990. The southwest Puerto Rico precipitation times series correlates positively with local and larger regional SST timeseries (Table 3), there is no relationship between the coral SST reconstruction and local precipitation, whereas removing local SST variability from the coral oxygen-isotope record results in a large negative correlation.

Table 3. *Pearson's r* and significance between southwest Puerto Rico precipitation timeseries and a suite of time series for a 55-year segment of the record (1936-1990)

1936 to 1990	r	prob	z
SSTs SW of Puerto Rico	-0.0504	0.5842E+00	-0.0504
SSTs SW of Puerto Rico	0.6369	0.5306E-14	0.7529
Tropical SSTs	0.5237	0.8339E-09	0.5815
AMO	-0.1384	0.1318E+00	-0.1392
PDI	0.5014	0.5447E-08	0.5511
Global SSTs	0.2243	0.1378E-01	0.2282
Global Surface Air Temperature	0.2567	0.4648E-02	0.2626
Coral Isotope minus local SSTs	-0.7003	0.5511E-18	-0.8679

5. Evaluation of Multidecadal climate variability in the coral $\delta^{18}O$ record

- Analyses of the instrumental record documents that the local region of the northwest Caribbean is representative of many aspects of large-scale multidecadal climate variability over the past 120 years.
- Analyses of the 1936 to 1990 segment of the oxygen isotope-derived SST from the La Parguera coral illustrate the potential of this paleoproxy record to reconstruct local, regional, and global multidecadal climate variability. Much of the 1936 to 1990 part of the coral record can be explained in term of the combination of local SST and precipitation variability, with the local precipitation influenced in turn reflecting tropical/global SST variability
- Interpretation of the 1881 to 1925 segment of the coral SSTreconstruction remains challenging. The combination of additional geochemical proxies for SST reconstructed from this coral record (e.g., Mg/Ca and Sr/Ca) and better local precipitation records extending into the 19th century are anticipated to improve our current understanding.